Spectrophotometry of Two Complete Samples of Flat Radio Spectrum Quasars

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Abstract

Spectrophotometry of two complete samples of flat-spectrum radio quasars show that for these objects there is a strong correlation between the equivalent width of the CIV λ1550 emission line and the luminosity of the underlying continuum. Assuming Friedmann cosmologies, the scatter in this correlation is a minimum for $q_o \approx 1$. Alternatively, luminosity evolution can be invoked to give compact distributions for $q_o \approx 0$ models. A sample of Seyfert galaxies observed with IUE shows that despite some dispersion the average equivalent width of CIV λ1550 in Seyfert galaxies is independent of the underlying continuum luminosity. We give new redshifts for 4 quasars.

Subject headings: cosmology -- galaxies: Seyfert - quasars - spectrophotometry

I Introduction

Baldwin (1977) suggested that a correlation existed between the strength of the Ly-α and CIV λ1550 emission lines of quasars and the luminosity of the underlying continuum radiation measured near the wavelength of the CIV line. Because the sense of the correlation was that the fainter, more difficult to observe, quasars had the strongest features, the possibility existed that much of the observed correlation was produced by optical selection effects. In this study we attempt to reduce, or eliminate, any such effects by observing all quasars in two complete radio samples. The objects were selected solely by accurate positional agreement between the radio source and a stellar object on the Palomar Sky Survey (PSS) plates. Flat spectrum radio objects were chosen, partly because the high frequency surveys give very accurate radio positions and partly because Baldwin (1977) found that the flat radio spectrum sources gave a slightly better correlation between continuum luminosity and line strength than quasars with other radio characteristics. Because strong emission lines can raise a faint quasar above the threshold for detection on PSS plates, the strong lined objects are probably overrepresented among the fainter souces. This is not a serious problem as it is possible to use the spectrophotometry to identify those objects that are in the sample becuase of their strong lines. It is more important to use the radio survey to set upper limits to the fraction of brighter, weak lined quasars that might exist and the number of bright, strong lined objects. We emphasize that the new QSO samples do not include <u>any</u> of the objects from the original study by Baldwin (1977).

A preliminary paper (Baldwin, Burke, Gaskell and Wampler; 1978) gave early results after a sample of the flat radio spectrum sources had been observed. In that paper it was suggested that MgII λ2800 might be a useful luminosity indicator for low redshift quasars. However, as the observations show a very poor correlation between the strength of MgII λ2800 and the continuum at λ2800, the observations of MgII λ2800 were discontinued in favor of IUE observations of a small sample of low redshift quasars from the two radio surveys. Also Tarenghi, Véron and Véron have communicated to us pre-publication measurements of the CIV λ1550 strengths and continuum magnitudes for 23 Seyfert galaxies and low luminosity quasars that have been observed by IUE. Their data, together with ours, define boundaries that set upper limits to the intensity of CIV λ1550 as a function of continuum luminosity. The observations of the complete radio samples and the ratio of BL-Lac objects to Seyfert galaxies per unit volume of space can be used to limit the number of faint, weak lined objects that could have been missed in the surveys.

In section II we give the observations together with a discussion of the possible observational errors and completeness of the surveys. The results are analyxed and discussed in section III and the principal conclusions are given in section IV.

II Observational Procedures, Results and Error Analysis

II.1. The data.

The quasars selected for observation were taken from two "complete samples" of flat spectrum radio sources: the NRAO 5-GHz S2 and I survey (Pauliny-Toth *et al.*; 1972) and the Parkes ± 4° survey (Masson and Wall; 1977). In the

Pauliny-Toth et al. (1972) catalogues there are 21 quasars that have radio spectral indexes flatter than 0.5 and redshifts above 1.13. For some of the objects in the catalogue both high and low frequency spectral indexes were given. When available we used the high frequency index as the criteria for acceptance of a candidate. We give spectrophotometry here for 20 of these 21 candidates. Photometry for the other, 1211+33, is given by Richstone and Schmidt (1980). There are in addition four other candidates that are acceptable from their radio properties. Of these, two were later classified as blank fields by Shaffer (1978), one, 1751+28, is present only as a very faint image near the limit of the blue PSS and the last, 2337+26, is uncertain and very red (Schmidt, private communication). Neither of these last two is listed in Shaffer (1978). About 25% of the identifications in Shaffer (1978) differ from those of Pauliny-Toth et al. (1972). We have observed 16 of the objects listed by Shaffer (1978). In addition we required candidates to have tabulated magnitudes brighter than 20 mag. Shaffer's list gives 8 objects that satisy the magnitude criteria but were not in the Pauliny-Toth et al. (1972) sample, and which we have therefore not observed. One, 2308+34, has spectrophotometry by Richstone and Schmidt (1980), another, 007+171, has spectroscopy by Wills and Wills (1976), in both cases giving redshifts which should place these objects within our sample. There is only one BSO among the remaining 6 candidates, the others are neutral or red stellar objects which are unlikely to be QSOs and only one of which is as bright as 18 mag. However, the choice of sources for observation was based on the earlier Pauliny-Toth et al. (1972) catalogue; the newer Shaffer (1978) identifications may be taken as the amount of uncertainty in the original identification procedure. It is unlikely that many additional candidates would surface from a third pass through the plate material, so we conclude that the Pauliny-Toth et al. (1972)

identifications constitute a complete sample to within about 3-4 QSOs. Because finding charts for the Pauliny-Toth et al. (1972) sources were not available when the observing program started Howard French kindly identified sources for us from computer generated overlays on PSS plates. We are also indebted to Maarten Schmidt for providing redshifts in advance of publication. This allowed us to reject low redshift quasars. It is rather remarkable that among the Pauliny-Toth et al. (1972) candidates there are no BL-Lac type objects. A few appear in the lists of Shaffer (1978) and one spectacular object, 0215+015, (Gaskell; 1982) earns candidate status on the basis of later radio spectroscopy (Wills and Lynds; 1978).

The Masson and Wall (1977) list contains 53 candidates with high frequency radio spectra flatter than 0.5, optical - radio positional agreement to $\lesssim 6$ arc seconds, estimated magnitudes brighter than 20 mag and right ascension not in the 7^h00^m-8^h59^m range. Of these 25 have $z \gtrsim 1.13$, two are stars or low redshift galaxies, 3 have continuous or BL-Lac type spectra, two have noisy spectra but are probably BL-Lac objects and the remainder have $z \lesssim 1.13$. There are five objects in this list that overlap the Pauliny-Toth et al. (1972) catalogue. Taken together the two lists give us 43 quasars. We have observed all but 1211+33, for which Richstone and Schmidt (1980) give spectrophotometry, and we have added 0421+01 because Wills and Lynds (1978) list a high frequency spectral index that places it in our sample.

Spectra of candidate objects were obtained at Lick Observatory using the Image Dissector Scanner (IDS) system (Miller, Robinson and Wampler; 1976) attached to the Shane 3-meter telescope. Typically the resolution of this system is 7Å FWHM. Spectra of candidate objects from the Masson and Wall (1977) samples were also obtained using the CTIO 4-meter telescope equipped with an intensified

silicon image tube (SIT) spectrophotometer. In addition a few spectra were obtained at the AAT using the IDS and photometry of 1705+018 was obtained at Las Campanas using the Schectrograph. The SIT spectrophotometer gives a typical resolution of 10Å. Large apertures were used to obtain absolute continuum magnitudes; typically 8 arc seconds at Lick Observatory and 10x60 arc seconds at CTIO. In order to improve the spectral signal-to-noise for line strength determination it was the practice at Lick Observatory to also observe each object with a small aperture in order to reduce the sky background. Spectra taken with small apertures were normalized to the large aperture spectra to correct for light loss due to differential atmospheric dispersion before measuring the equivalent widths. The spectrophotometric observations were calibrated by observing standard stars from the lists of Stone (1974). This calibration is traceable to the Hayes (1970) calibration of bright stars.

Five quasars that were sufficiently bright to observe with International Ultraviolet Explorer (IUE) were chosen from the low redshift portion of the two surveys. The observing journal for these 5 objects is given in Table 1. In addition Ulrich et al. (1980) have published spectrophotometry from extensive IUE observations of 3C 273, a member of the Masson and Wall (1977) list. These six low redshift members are useful in checking the continuum luminosity, CIV λ1550 line strength correlation for nearby quasars and to anchor the low redshift position of the Hubble curve. The IUE integration times were very long and required collaborative observations between VILSPA and Goddard Space Flight Center. The IUE data were reduced using the standard IUE reduction package and calibration tables. At the European Southern Observatory (ESO) a reduction program developed by Massimo Tarenghi removes sharp noise spikes from the two dimensional geometric and photometric correct images that are available

on the IUE guest observer tapes. The program then extracts the data from the two dimensional frame. This procedure results in spectra that have less noise than the standard IUE reduced spectra which are provided on the guest observer tape. While the "ESO reduced" spectra were used to determine the continuum magnitudes and CIV λ1550 line strengths a comparison of the ESO and IUE reductions showed no systematic offsets. We are grateful to Massimo Tarenghi for giving us his program and explaining its use to us.

Philippe Véron, Mira Véron and Massimo Tarenghi (private communication) have provided us with mean λ1550 continuum magnitudes and CIV λ1550 equivalent widths for a large number of Seyfert galaxy spectra that are available in the IUE archives. These data were reduced using the ESO program mentioned above. The continuum levels and CIV λ1550 equivalent widths were determined using an interactive program developed for the ESO data processing system. We include the Seyfert galaxy data here, even though the selection of objects was not controlled by considerations of completeness, as it is instructive to compare the properties of the Seyfert spectra to those of the quasars.

In Table 2 we give the observational data for the high redshift quasars in the flat spectrum samples and the data for Seyfert galaxies from Véron, Véron and Tarenghi (private communication). For some objects, such as 3C 120, the data given here, which are based on additional spectra, differ substantially from earlier published results (Oke and Zimmerman; 1979). In columns 1-3 we give the name of the object, the source for the identification and its redshift. In column 4 we give the observed continuum magnitude at the wavelength corresponding to the redshifted position of λ1550. This continuum magnitude, AB_{1550}, is defined as:

$$AB_{1550} = -2.5 \log f\nu_{1550} - 48.60$$

where $f\nu_{1550}$ is the observed flux at the redshifted position of λ1550 in ergs s^{-1} cm^{-2} hz^{-1}. In column 5 we give the galactic reddening correction estimated from the HI maps published by Burstein and Heiles (1982). The reddening correction is not included in the tabulated observed magnitudes, AB_{1550} but is included in the plots given in Fig. 4-6. Column 6 gives the equivalent width of the CIV λ1550 line in the rest frame of the quasar. In the case of 2251+245 a very strong absorption feature blankets the CIV λ1550 emission line. Consequently, the strength of the emission line is very uncertain and we have not plotted this object in our figures. Column 7 gives the redshift corrected magnitude, M_{1550}, defined as:

$$M_{1550} = AB_{1550} - 2.5 \log \left(\frac{z^2}{1+z}\right) - 43.91 - A_{1550(1 + z)}.$$

This redshift correction is appropriate for Friedmann cosmologies in which qo = 1; $A_{1550(1 + z)}$ is the reddening correction and a scaling constant was chosen so that M_{1550} would be the absolute magnitude if $H_o = 50$. Finally in column 8 we give the telescope(s) that were used to observe the source.

II.2 Error Analysis.

Rybski (1980) has found that the gain of the IDS systems at McDonald Observatory are a function of the exposure time. The effect that he observes could systematically decrease the magnitudes that we measure for faint objects compared to the standard stars, which were mostly 10-12 mag., by as much as 0.25 mag. Also Massy (1977) found that the magnitudes determined by Robinson and Wampler (1973) for galaxies in the cluster Shakhbazian 1 were one to 1.5 mag. too bright when compared to his photometry. Robinson and Wampler (1973) determined the magnitudes photographically but the calibration was established

by the IDS system. However other comparisons at Lick Observatory of IDS magnitudes with data from scanners equipped with photomultiplier detectors showed no large errors. The present set of data and the availability in the literature of extensive observations obtained by a number of observers using a variety of techniques permits a thorough study of our systematic and random errors. We give here the results of the comparison of our data with that of others as well as the intercomparison of our observations taken on different telescopes.

Because quasars vary in brightness, comparisons of observations obtained on different dates will be subject to brightness differences as well as differences caused by photometric errors. But if a large number of objects are observed the uncorrelated variability only serves to increase the scatter of the observational points. Systematic effects, if any, may still be found and limits may be placed on the amount of variability in the source or the amplitude of the observational errors.

From the Lick Observatory data continuum magnitudes were determined graphically using eye estimated linear fits to computer plots of the spectra. The equivalent widths of the emission lines were determined by planimetry of the plots. Allowances were made for absorption lines and HeII $\lambda1640$, a weak line that is blended with the red wing of CIV $\lambda1550$. For the observations obtained at CTIO and the AAT continuum fluxes and the equivalent width of the lines were found using an interactive computer program. The internal errors for the northern and southern hemisphere set of observations were about the same. Excluding a few obviously variable objects comparison of repeated observations suggests an internal continuum accuracy of about 10% for the brighter sources that decreases to about a factor of two uncertainty for the faintest objects. The

internal accuracy of the equivalent width measurements is about 30% for the bright sources and about a factor of two for the faint ones. The uncertainties in the continuum level are the major component in the uncertainty of determining the equivalent width of the emission lines for the faint quasars. For the brighter objects uncertainties in the measurements of the shallow, extended wings of the lines contributed substantially to the uncertainties of the measurements.

An intercomparison between the magnitudes obtained at Lick Observatory and data from other observers is given in Fig. 1. The agreement between the Lick and CTIO continuum measurements is in general accordance with the error estimates. This agreement between the continuum magnitudes in particularly noteworthy as the CTIO observations were obtained with the integrating television system on the 4-meter telescope. This system might not be subject to the non-linearities described by Rybski (1980) which could affect the IDS magnitudes.

The broad band observations shown in Fig. 1 are derived from the PSS, either measured or eye estimates. As they include the effect of emission lines excluded by the scanners they should give somewhat brighter magnitudes than are determined by the scanners. Also since the PSS data was obtained about 25 years before our data were collected the intercomparison of scanner data with PSS data will contain the effects of slow quasar variability that would be only weakly present in measurements which are nearly contemporary with the scanner data. Again the agreement is quite good. The observed systematic shifts can be explained as due to the influence of strong emission lines while the scatter of the points is in fact no larger than would be expected from the

estimates of the observational error. This shows that most of the quasars are approximately constant in light output even over long periods of time. It is worth noting, however, that the dispersion of the points about a mean line increases very rapidly for sources fainter than about magnitude 18.5. This increased dispersion may be due entirely to the uncertainties in estimating magnitudes of objects that are near the limit of the PSS plates. However the possibility remains that, since our quasars have similar redshifts, the observationally faint sources are also intrinsically faint and the increased dispersion may be partly caused by increased variability of the fainter quasars.

Narrow band data is available from a number of sources. Oke and Korycansky (1982) have published scans of high redshift quasars using the Palomar Multichannel Spectrometer. While none of the objects observed by them are included in this study, six of their sources have been observed by Baldwin (1977) using the Lick Observatory IDS scanner in his initial investigation of the CIV $\lambda 1550$ continuum luminosity effect. Because the earlier data were obtained using the same techniques and equipment used here a comparison between the results of the two investigations can yield useful information on the linearity and accuracy of the IDS system. These data are also shown in Fig. 1b. While the Baldwin (1977) magnitudes are slightly fainter than those found by Oke and Korycansky (1982) there is in general very good agreement between the IDS data and the data obtained using the Palomar Multichannel Spectrometer.

For a number of quasars observed in this study Richstone and Schmidt (1980) have also published continuum fluxes and CIV $\lambda 1550$ equivalent widths obtained from observations using the Palomar Multichannel Spectrometer. Richstone et al.

(1980) has supplemented these measurements with additional data from observations taken with a TV-type spectrophotometer used at Palomar Observatory. It is necessary to convert the log f_{2500} measurements tabulated by Richstone and Schmidt (1980) and Richstone et al. (1980) to the AB_{1550} magnitudes we use. We do this by calculating

$$AB_{1500} = -2.5 (\log f_{2500} + \alpha (0.208)) - 48.60$$

where f_{2500} and α are taken from their tables. Using a model they describe we have also removed the correction for galactic absorption that is included in their data.

A comparison between these data and ours (see Fig. 1b) does not show good agreement. The scatter seen in Fig. 1b for the continuum magnitude comparison is much larger than can be explained either from the internal error estimates or, in view of the lower dispersion seen in comparison with broad band data, from plausible variations in the sources. The explanation for these discrepancies is not known.

Comparison between the equivalent width measurements of CIV λ1550 is shown in Fig. 1. Satisfactory agreement exists between the CTIO and Lick observations and between the Lick IDS data published by Baldwin (1977) and the multichannel scanner data given by Oke and Korycansky (1982). The equivalent width measurements published by Young <u>et al</u>. (1982a, b) are systematically smaller than those found here. However a number of ionic species: He^{+}, O^{++}, and N^{++} have weak lines extending to 1640 angstroms. As the high resolution spectra of Young <u>et al</u>. (1982a, b) do not extend very far into the red it is possible

that their adopted continuum levels were somewhat too high. Finally we note the scatter in the comparison between the Richstone and Schmidt (1980) equivalent widths and those given here which is unexplained.

The comparison of our data with that of others leads us to conclude: a) The IDS systems used at Lick Observatory and at the AAT and the intensified silicon camera used on the CTIO spectrophotometer are capable of linear photometric observations of faint objects. b) Most of the bright quasars are reasonably constant in light output for long periods of time. However there is sufficient scatter in the data of the faint sources that the possibility remains that intrinsically faint quasars are more variable than the bright ones. c) Different observers can produce data with discrepancies that are at least an order of magnitude larger than the quoted errors. Care should be exercised when combining data from different observers.

It is much more difficult to assess the errors in determining the continuum flux and CIV λ1550 equivalent width from the IUE observations. There is, as yet no independent spectrophotometry for these sources. Fig. 3 shows the IUE spectra obtained for the five low redshift quasars we observed as part of our luminosity investigation. We are indebted to R. F. Carswell and E. H. Smith for the IUE spectrum of PKS 1217+02. As these quasars are near the limiting sensitivity of IUE, the spectra have substantial shot noise together with an increased chance for calibration errors. For the Seyfert galaxy data the IUE spectra frequently had many emission and/or absorption lines which made determination of the continuum level difficult (Véron, private communication). Thus it is likely that the errors in the IUE spectrophotometry are at least as great as those found in the higher redshift sample observed from the ground.

III Luminosity - W(CIV) Correlations

In Fig. 4 we give plots of the continuum magnitude at the redshifted position of CIV λ1550 as a function of the logarithm of the equivalent width of CIV in the rest frame of the quasar. This figure shows that similar correlations between magnitude and equivalent width of CIV λ1500 exists for quasars at different redshifts. In this diagram the flat radio spectrum quasars are divided into three groups: 3C 273 together with the six low redshift quasars observed by IUE, quasars with redshift between 1.1 and 1.9 and quasars with redshifts between 1.9 and 2.6. For the low redshift objects we give the absolute magnitudes assuming $q_o = 1$ and $H_o = 50$. Other cosmologies yield nearly identical results for the low redshift group. For the two higher redshift samples the observed magnitudes are plotted. Because the redshift differences in each of the two high redshift samples are small, differential cosmological corrections within a group are also small and it is useful to view obwerved magnitudes when assessing observational selection effects. In Fig. 4 all the magnitudes have been corrected for Galactic absorption before the points were plotted.

We believe that we have observed nearly all the quasars with continuum magnitudes brighter than 19.5 and redshifts greater than z = 1.13 that are identified by the two flat spectrum radio surveys. These objects show the correlation between luminosity and CIV equivalent width. The inclusion of quasars with continuum magnitudes fainter than 19.5 strengthens the correlation. But the radio surveys may be incomplete for objects with continuum magnitudes fainter than 19.5 since for them the presence of strong emission lines increases the chance that the object will register well exposed images on the sky survey plates. If we restrict our attention to the brighter objects we note that

even if all of the approximately half dozen BL-Lac objects found in this survey have high redshift and populate the low equivalent width, low luminosity part of the diagram, they are insufficiently numerous to produce the rapid increase in the numbers of faint, weak lined sources proposed by Osmer (1980) to explain the absence of bright strong lined sources as a consequence of random sampling in a population whose space density increases rapidly with decreasing brightness and line strength. Thus it is clear that these two samples of flat spectrum radio sources show substantial intrinsic structure in their two dimensional luminosity / W(CIV) distribution. The existence of such structure gives an important clue to the nature of the emission line region and can, in principle, be used as a "standard candle" for cosmological studies.

In Fig. 5 we plot all our observations on a magnitude - log W(CIV) plot using Friedmann cosmologies with $q_o = 0$ and $q_o = 1$. The observed magnitudes were corrected by a factor $-2.5 \log (z^2/1+z)$ for the $q_o = 1$ case and by $-2.5 \log (z + \frac{1}{2} z^2)^2/(1+z)$ for the $q_o = 0$ case. If a Friedmann cosmology with $q_o = 0$ is used the lower redshift quasars are subluminous in comparison with the higher redshift ones. The group of quasars observed with IUE are among the brightest of the lowest redshift group. If q_o is taken to be one, all the quasars would be approximately comparable in luminosity. There is no evidence that the spectra of the high and low redshift group of quasars are substantially different. Baldwin's (1975) comparison of the optical spectra of 3C 273 and 0736+017 showed that it was possible for quasars differeing in luminosity by nearly three magnitudes to have very similar equivalent wiedths for emission lines in the $2700 < \lambda < 7000$ Å region. But the IUE observations given here for 0736+017, although a low weight, suggest that the CIV λ1550 line in 0736+017 has a much higher equivalent width than th corresponding line in 3C 273. Thus we find no spectroscopic data to suppo. .ne concept that there

is luminosity evolution of the type required to reconcile our observations with the predictions of an open Friedmann universe. While, of course, it is possible that reality may require a totally different cosmological formulation than the widely used Friedmann model or that the emission line spectra of quasars are insensitive to luminosity evolution, we note that these data can be reconciled with a closed Friedmann universe in which $q_o = 1$.

When the Seyfert galaxy data from the sample of Tarenghi, Véron and Véron are added to the magnitude, log W(CIV) plot an interesting interpretation of the data suggests itself. The Seyfert galaxies all have strong CIV λ1550 lines when compared to the quasars. Over half of the quasars from our samples have weaker CIV λ1550 lines than all but four of the 28 Seyfert galaxies. Fig. 6 shows the combined data for the Seyfert galaxies and quasars with the assumptions that $q_o = 1$ and $H_o = 50$ km/sec/Mpc. The Seyfert galaxy data plotted here lie in the same part of the log continuum luminosity/log equivalent width diagram as the data given by Wu et al. (1982). They found a correlation between the equivalent width of the CIV λ1550 emission line and the continuum luminosity that is not confirmed by the data from Tarenghi, Véron and Véron. These data suggest that all Seyfert galaxies have comparable CIV λ1550 equivalent widths with a dispersion of approximately a factor of two about a mean value of 100Å. The bright end of the Seyfert distribution joins smoothly with the faint end of the quasar relationship. For $q_o = 1$ and $H_o = 50$ this occurs at an absolute continuum magnitude of about − 24. For objects brighter than $M_{1550} = -24$ the average strength of CIV λ1550 fails to increase as rapidly as the continuum magnitude. In fact it is possible to define a lower envelope to the quasar M_{1550}/log W(CIV) plot that has a slope corresponding to constant CIV line strength.

While $W_{1549} \sim$ const. for Seyferts can easily be understood in terms of complete coverage of the central photoionizing source it is not so easy to understand why the CIV line for flat radio spectrum quasars show the CIV line luminosity tending to a constant value and the equivalent width decreasing with increasing continuum luminosity. The lower equivalent width of quasars can mean any of the following things:

a) The observed continuum does not extrapolate to the C^{++} ionization edge (259 Å) but instead turns sharply down before then. Observations of very high redshift quasars do not support this.

b) Some of the continuum we see is beamed towards us and does not contribute to the photoionization of the broad line clouds. This is believed to be the case in BL Lacertae objects and the optically violently variable quasars.

c) The average cloud size is smaller than the Strömgren length in quasars, i.e., the clouds are matter bounded rather than radiation bounded.

d) The covering factor is lower in quasars than Seyferts.

Further observations are needed to distinguish between these possibilities.

V Conclusions

The addition of new optical data from two complete samples of flat spectrum radio sources confirms and strengthens the conclusions reached by Baldwin (1977) and Baldwin et al. (1978) that there is a strong correlation between the strength of the CIV λ1550 lines in quasars and the luminosity of the underlying continuum. These two new samples are completely independent of the QSO sample which

originally suggested this correlation. The suggestion by Wu et al. (1982) that Seyfert galaxies show a similar correlation, only displaced, is not confirmed by this data. Instead, these data suggest that the equivalent width of CIV λ1550 in Seyfert galaxies has some real scatter but on the average is constant and independent of continuum luminosity. Seyfert galaxies appear to have an upper limit to the equivalent width of their CIV λ1550 emission which is nearly constant for absolute continuum magnitudes that range over 8 magnitudes. The quasars, however, seem to have an upper limit to the absolute luminosity of their CIV λ1550 lines which range over an additional four magnitudes of contiuum luminosity. Spectra of all quasars detected in two complete surveys of flat spectrum radio sources show that contrary to Osmer's (1980) proposal there are too few faint weak lined quasars for this upper limit to be explained as a sampling effect in a bi-modal power law distribution of line strength and continuum luminosity. The data fit the predictions of Friedmann cosmologies with $q_o = 1$ without invoking an arbitrary luminosity evolution that is needed for fits to open universes.

The observational errors have been investigated, both by internal checks and through the comparison of these data with that of others. These checks generally show satisfactory agreement. Thus there is strong evidence that the spectrophotometers used in this investigation are linear and are capable of accurate photometry. The small scatter found in the comparison of data taken at different times for the brighter quasars demonstrates that most of these flat spectrum radio sources are not large amplitude variables even over a 25 year base line.

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Table 1

IUE Observing Log for Low Redshift Quasars

Name	Date (1981)	exp. (min)	Camera
0736+017	Dec. 9	410	SWP 15692
	Dec. 16	883	SWP 15773
0742+318	April 16	410	LWR 10366
	Dec. 18	500	LWR 12177
1103-006	July 22	620	LWR 11111
1146-037	July 18	420	LWR 11084
	July 20	650	LWR 11098
	Dec. 17	645	LWR 12158
1217+023	July 15	684	SWP 14476

Table 2

Magnitudes and CIV λ1550 Equivalent Widths

Name	Sample[3]	Z	AB_{1550}	$A_{1550}(1+z)$	log W_o (CIV)	M_{1550}[5]	Telescope[4]
0103-021	1	2.201[1]	19.84	0.00	1.94	-24.52	1
0106+013	1,2	2.107	18.42	0.00	1.72	-25.87	1,2
0112-017	1	1.366	18.36	0.00	1.48	-25.29	1,2
0119+247	2	2.025	19.50	0.23	2.04	-24.97	2
0146+056	2	2.35	21.6:	0.10	2.37	-22.95	2
0149+218	2	1.32[1]	20.76	0.29	2.06	-23.13	2
0149+335	2	2.426	18.64	0.20	1.58	-26.06	2
0202+31	2	1.472	18.23	0.28	1.57	-25.81	2
0226-038	1	2.064	17.62	0.00	1.34	-26.65	1
0229+130	2	2.065	19.10	0.00	1.93	-25.17	2
0234+285	2	1.207	18.91	0.41	1.65	-24.96	2
0400+258	2	2.109	21.23	0.40	2.07	-23.47	2
0421+019	2	2.048	17.59	0.22	1.32	-26.89	2
0454+039	1	1.349	17.05	0.29	1.49	-26.87	2
0457+024	1,2	2.378	19.40	0.20	1.66	-25.27	2
0458-020	1	2.286	19.53[2]	0.24	1.87	-25.12	2
0504+030	1,2	2.463	18.57	0.30	1.31	-26.25	1
0736+017	1	0.191	17.95	1.05	1.81:	-23.23	5
0742+318	2	0.462	16.34	0.23	1.58	-25.71	5
0748+333	2	1.928	18.04	0.12	1.71	-26.25	2
0922+005	1	1.720	18.01	0.00	1.40	-25.99	1,2
1004-018	1	1.214	20.8:	0.00	2.2:	-22.67	1,2,3
1010+350	2	1.413	20.4	0.00	2.08	-23.30	2
1018+348	2	1.404	19.03	0.00	1.92	-24.66	2
1021-006	1	2.548	19.19	0.00	1.99	-25.38	2
1103-006	1	0.426	16.80	0.24	1.45	-25.11	5
1146-037	1	0.341	18.19	0.00	2.32	-23.07	5
1048+340	2	2.52[1]	20.45	0.10	2.13	-24.20	2
1148-00	1	1.982	17.63	0.00	1.54	-26.58	1,2
1217+023	1	0.240	17.06	0.00	2.10	-23.51	5
1226+02	1	0.158	13.4	0.00	1.05	-26.34	5
1351+021	1	1.606	18.50	0.04	1.58	-25.44	1
1356+022	1	1.329	18.82	0.00	1.49	-24.78	1,2
1402-012	1	2.522	18.37	0.10	1.68	-26.28	1,2
1449-012	1	1.314	18.15	0.15	1.59	-25.59	2,3
1532+017	1	1.42[1]	18.65[2]	0.28	1.32:	-25.34	1
1602-001	1	1.633	18.13[2]	0.39	1.48	-26.18	1,2
1611+343	2	1.396	18.68[2]	0.00	1.76	-25.01	2
1615+026	1	1.336	17.82	0.34	1.44	-26.14	3
1656+348	2	1.934	18.72	0.00	1.54	-25.45	2
1705+018	1	2.58	19.36	0.28	1.62	-25.50	1,4
2134+004	1,2	1.930	17.39	0.16	1.55	-26.94	2

Table 2

Magnitudes and CIV λ1550 Equivalent Widths

Name	Sample[3]	Z	AB_{1550}	$A_{1550}(1+z)$	log W_o (CIV)	M_{1550}[5]	Telescope[4]
2223+210	2	1.959	18.19	0.15	1.33	-26.15	2
2243-032	1	1.348	18.10[2]	0.29	1.72	-25.82	2
2251+245	2	2.328	18.58	0.21	1.0::	-26.07	2
2254+024	1,2	2.090	18.10	0.11	1.47	-26.30	2
2320-035	1	1.396	19.15	0.14	1.60	-24.68	2
2328+107	2	1.49	18.83	0.14	1.40	-25.10	2
2332-017	1	1.185	18.30[2]	0.10	1.59	-25.23	2
Mark 335	3	0.025	14.56	-	1.72	-21.31	5
III Zw 2	3	0.090	16.13	-	2.08	-22.46	5
I Zw 1	3	0.061	16.54	-	1.56	-21.23	5
F 9	3	0.045	13.53	-	1.67	-23.60	5
NGC 985	3	0.042	15.25	-	1.77	-21.73	5
3C 120	3	0.032	16.75	-	2.26	-19.65	5
Akn 120	3	0.033	14.98	-	1.82	-21.49	5
Mark 79	3	0.022	16.00	-	1.99	-19.60	5
NGC 3516	3	0.009	16.38	-	2.05	-17.29	5
NGC 3783	3	0.009	16.40	-	2.26	-17.27	5
NGC 4051	3	0.002	16.75	-	1.79	-13.66	5
Mark 205	3	0.070	16.98	-	2.06	-21.08	5
NGC 4593	3	0.008	16.20	-	2.02	-17.22	5
Mark 279	3	0.031	15.41	-	1.95	-20.92	5
NGC 5548	3	0.017	15.48	-	2.34	-19.56	5
Mark 506	3	0.043	16.44	-	2.16	-20.59	5
3C 382.0	3	0.0578	16.49	-	2.19	-21.17	5
ESO 141-G55	3	0.037	14.50	-	1.83	-22.21	5
Mark 509	3	0.0355	15.13	-	2.16	-21.49	5
II Zw 136	3	0.061	15.83	-	1.66	-21.94	5
NGC 7213	3	0.0057	17.03	-	2.28	-15.65	5
Mark 304	3	0.067	16.35:	-	1.83:	-21.44	5
MR 2251-178	3	0.068	15.94	-	2.27	-22.06	5
NGC 7469	3	0.016	15.41	-	2.01	-19.50	5
Mark 926	3	0.047	15.39	-	2.29	-21.83	5

Notes to Table 2:

1. New redshift.

2. The magnitudes measured on different nights are not in agreement. The object is a suspected variable.

3. The code for the samples is as follows: 1. Masson and Wall (1977); 2. Pauliny-Toth *et al.* (1972); 3. Véron, Véron and Tarenghi (private communication). The data for 1226+02 (3C 273) is from Ulrich *et al.* (1980).

4. The code for the telescopes is as follows: 1. CTIO 4-meter; 2. Lick Observatory 3-meter Shane telescope; 3. Anglo-Australian 4-meter; 4. 2.5-meter at Las Campanas Observatory; 5. International Ultraviolet Explorer.

5. A Friedmann cosmology with $q_o = 1$ and $H_o = 50$ km/sec/Mpc is assumed.

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Figure Captions

Fig. 1: Comparison between magnitudes: a) Lick AB_{1550} and AB_{1550} obtained by Baldwin (CTIO) for this study (points) or given by Osmer (1977) (crosses). b) Comparison between AB_{1550} and Richstone et al. (1980) or Richstone and Schmidt (1980) magnitudes (points) and between Baldwin (1977) magnitudes and Oke and Korycansky (1982) (crosses). c) AB_{1550} given here and Masson and Wall eye estimate magnitudes from the Palomar Sky Survey. d) AB_{1550} given here and Wills and Lynds (1978) magnitudes. For quasars with $z < 1.6$ the blue magnitude was used; for higher redshift quasars the V magnitude was used.

Fig. 2: Comparison between log W (CIV): Left, Lick values against those determined by Baldwin (CTIO) for this study (points) or given by Osmer (1977) (crosses). Right, Lick values against values given by Richstone et al. (1980) or Richstone and Schmidt (1980) (points) or Young et al. (1982a, b) (open circles). Comparison between Baldwin (1977) Lick values against those given by Oke and Korycansky (1982) (crosses).

Fig. 3: IUE spectra of 5 low redshift quasars taken from the two complete radio samples.

Fig. 4: Absolute continuum magnitudes corrected for Galactic absorption against the logarithm of the equivalent width of CIV λ1550 measured in the rest frame of the quasar. Crosses, low redshift quasars measured with IUE. Points, quasars with $1.1 < z < 1.9$. Open

circles, quasars with $1.9 \lesssim z < 2.6$.

Fig. 5: Absolute continuum magnitude plotted against the logarithm of the rest frame equivalent width of CIV λ1550 in the two complete samples. The symbols are crosses, IUE data for low redshift quasars; points, quasars with $1.1 < z \lesssim 1.9$; open circles, quasars with $1.9 < z < 2.6$.

Fig. 6: Absolute continuum magnitudes against the logarithm of the rest frame equivalent width of CIV λ1550 for objects in Table 2 plus the observations of flat radio spectrum quasars from Baldwin (1977) (open circles). High redshift members of the two complete radio samples, filled circles, low redshift members, crosses. Vertical bars, Seyfert galaxies from Véron, Véron and Tarenghi (private communication). Quasar magnitudes have been corrected for the effects of Galactic absorption: Seyfert galaxy magnitudes, not. A Friedmann cosmology with $q_o = 1$, $H_o = 50$ is assumed.

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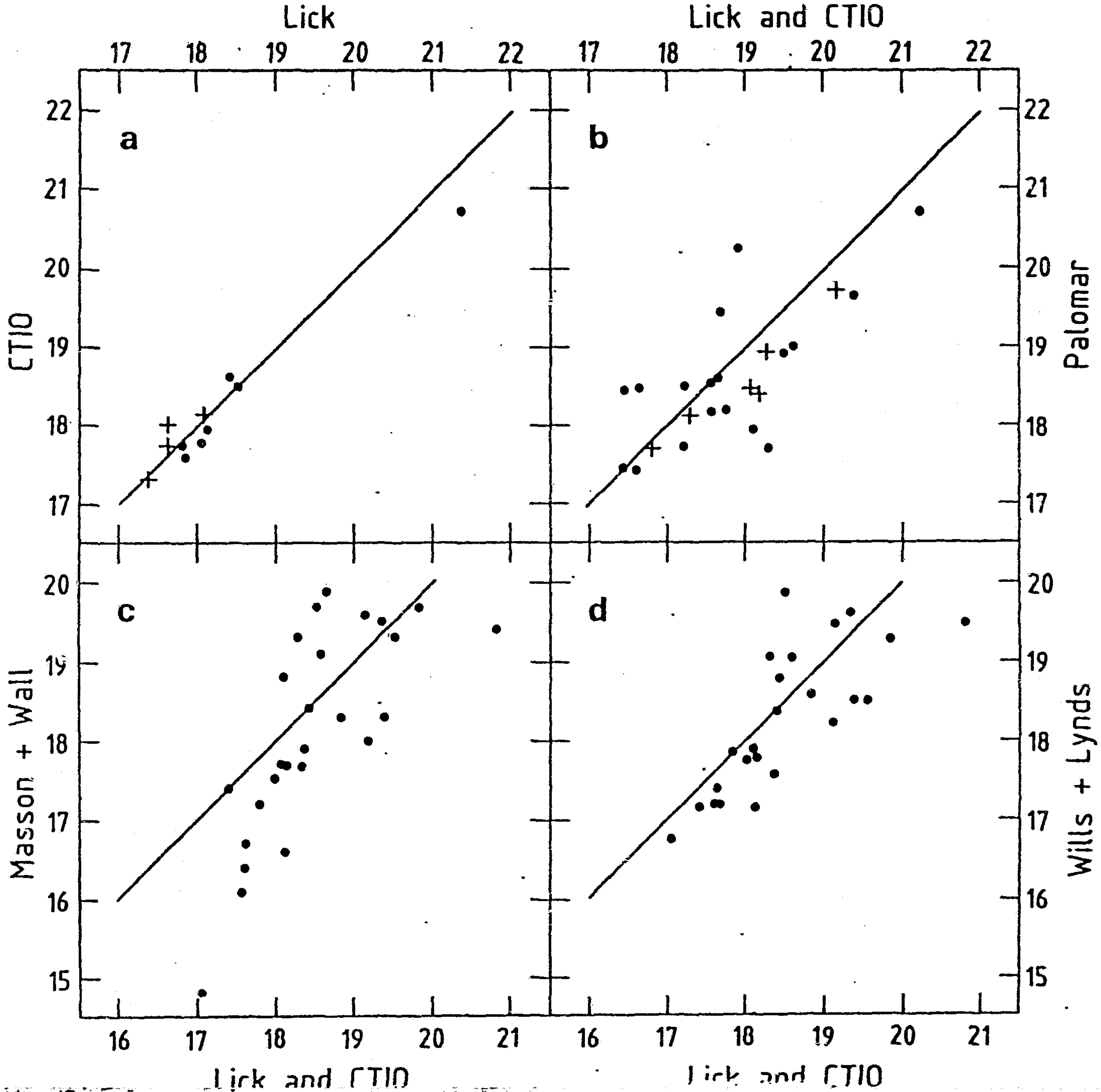
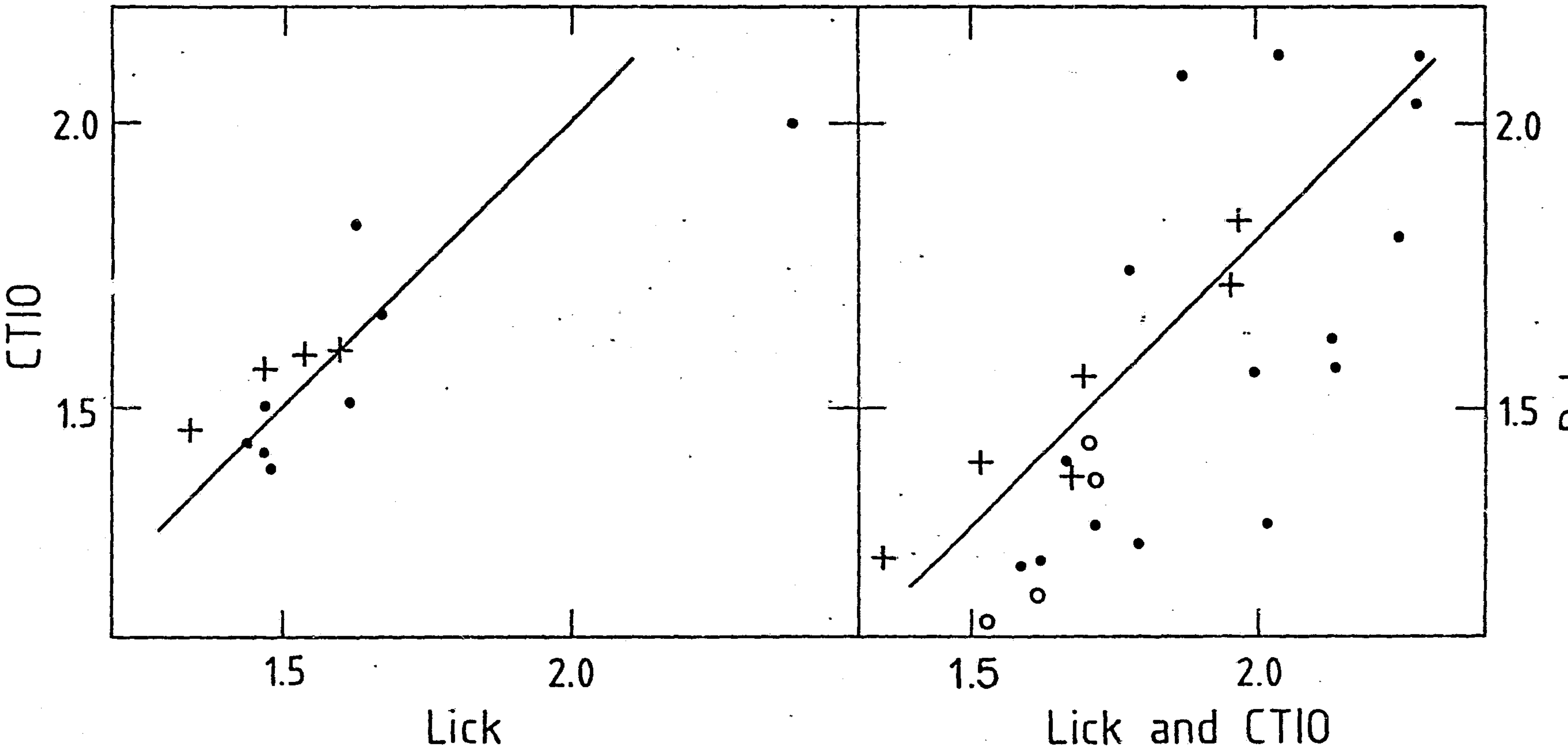


Lick
Lick and CTIO
a
b
c
d
CTIO
Palomar
Masson + Wall
Wills + Lynds
Lick and CTIO
Lick and CTIO



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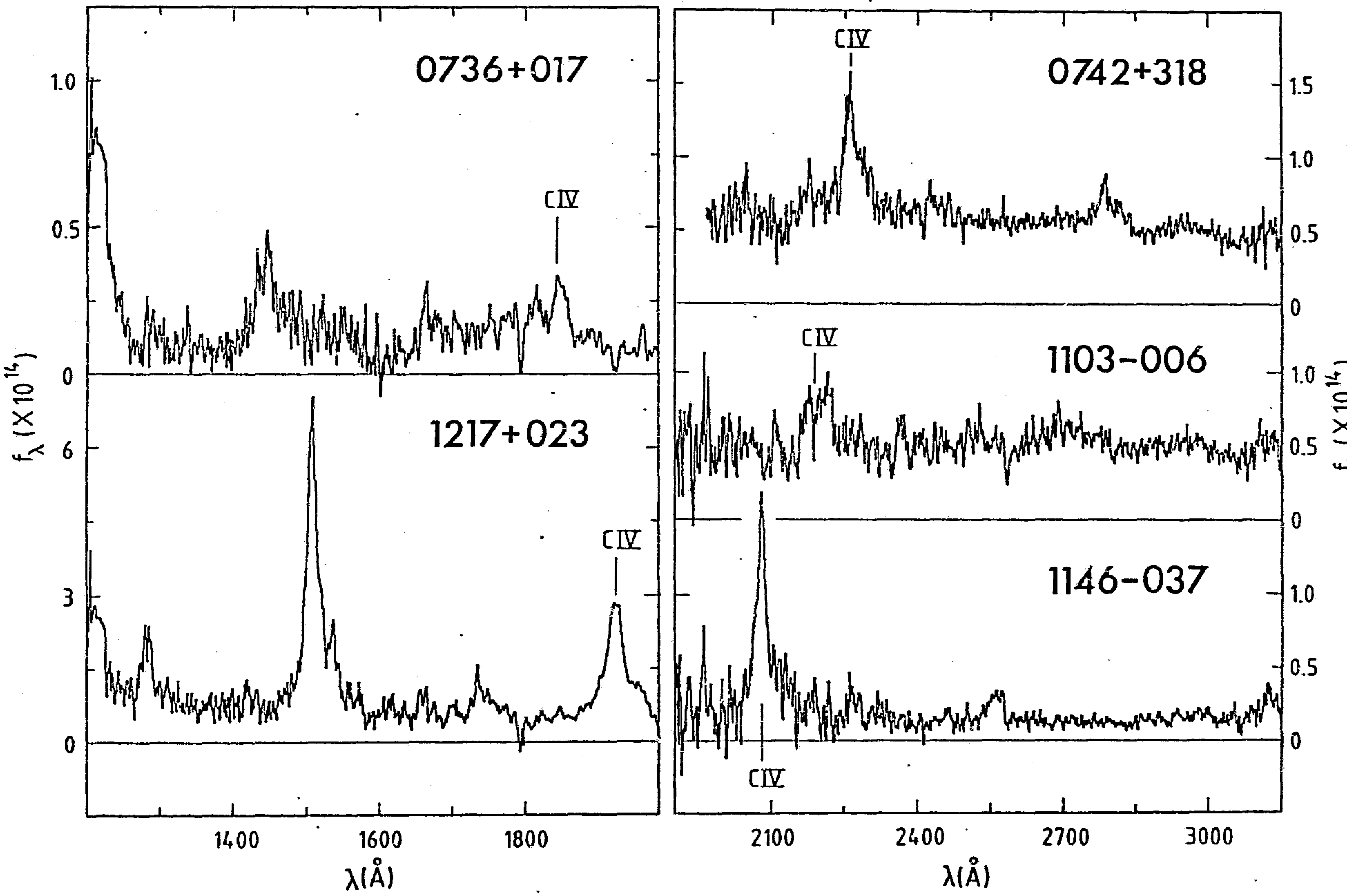
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3
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2100
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λ(Å)
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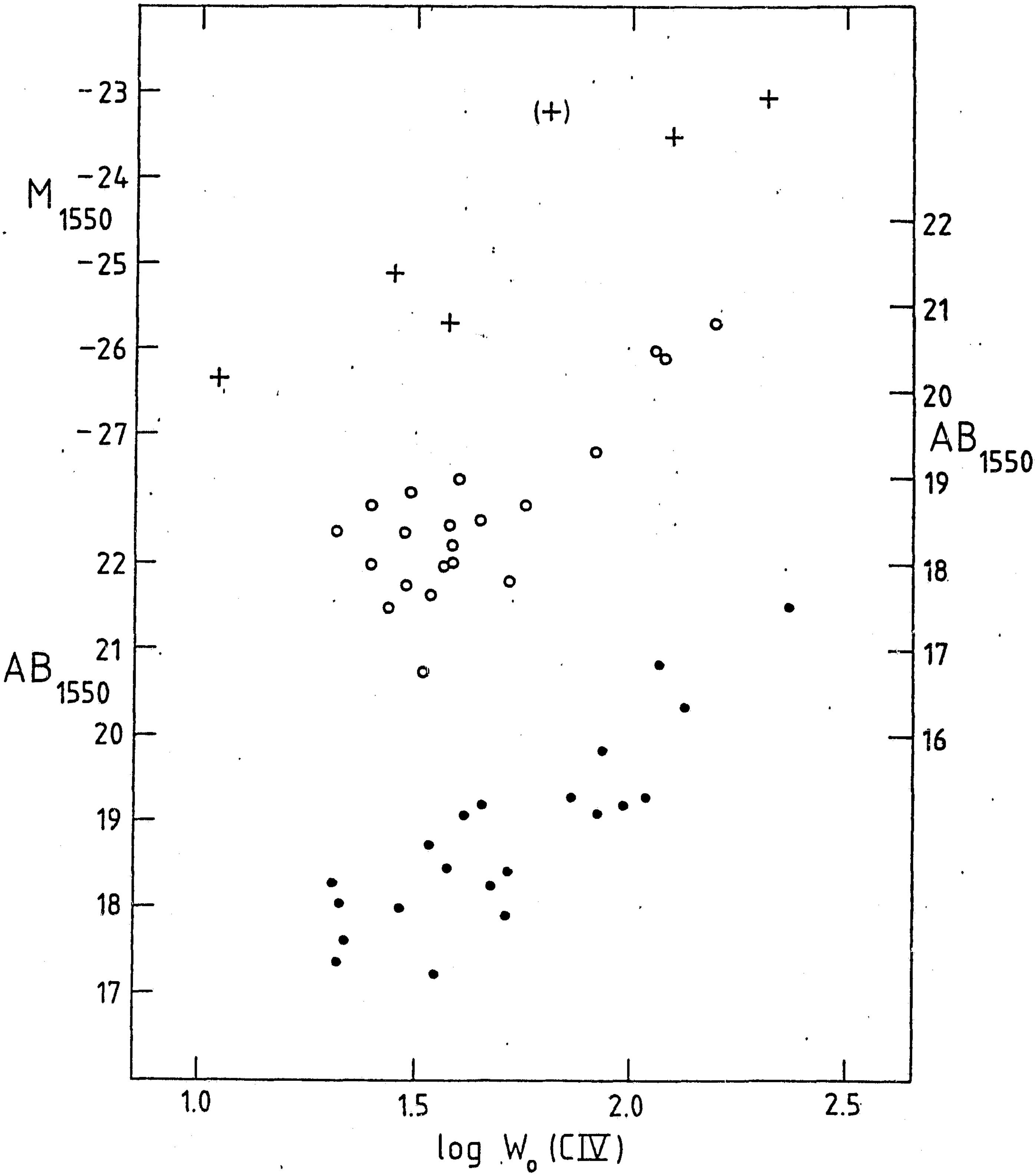

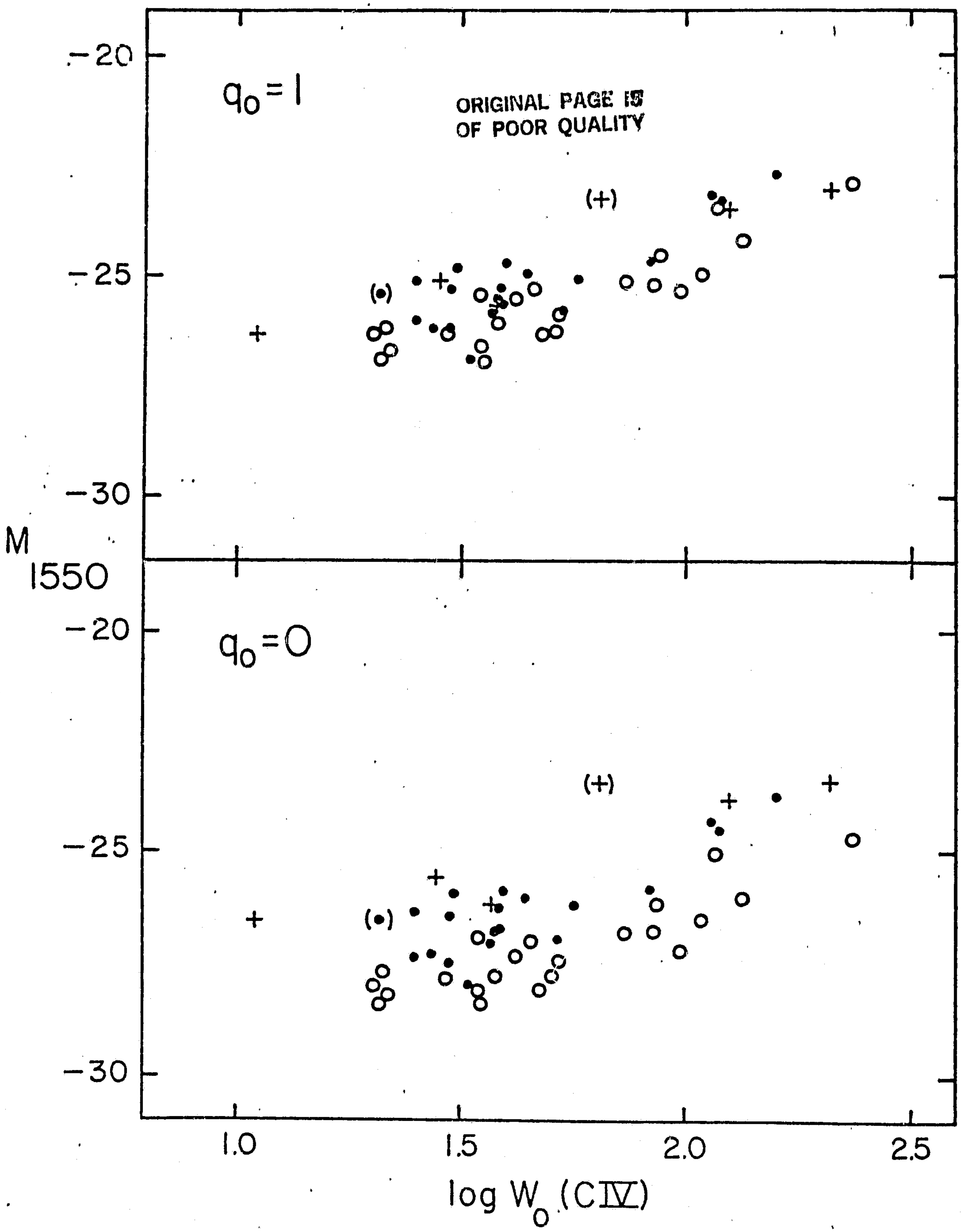

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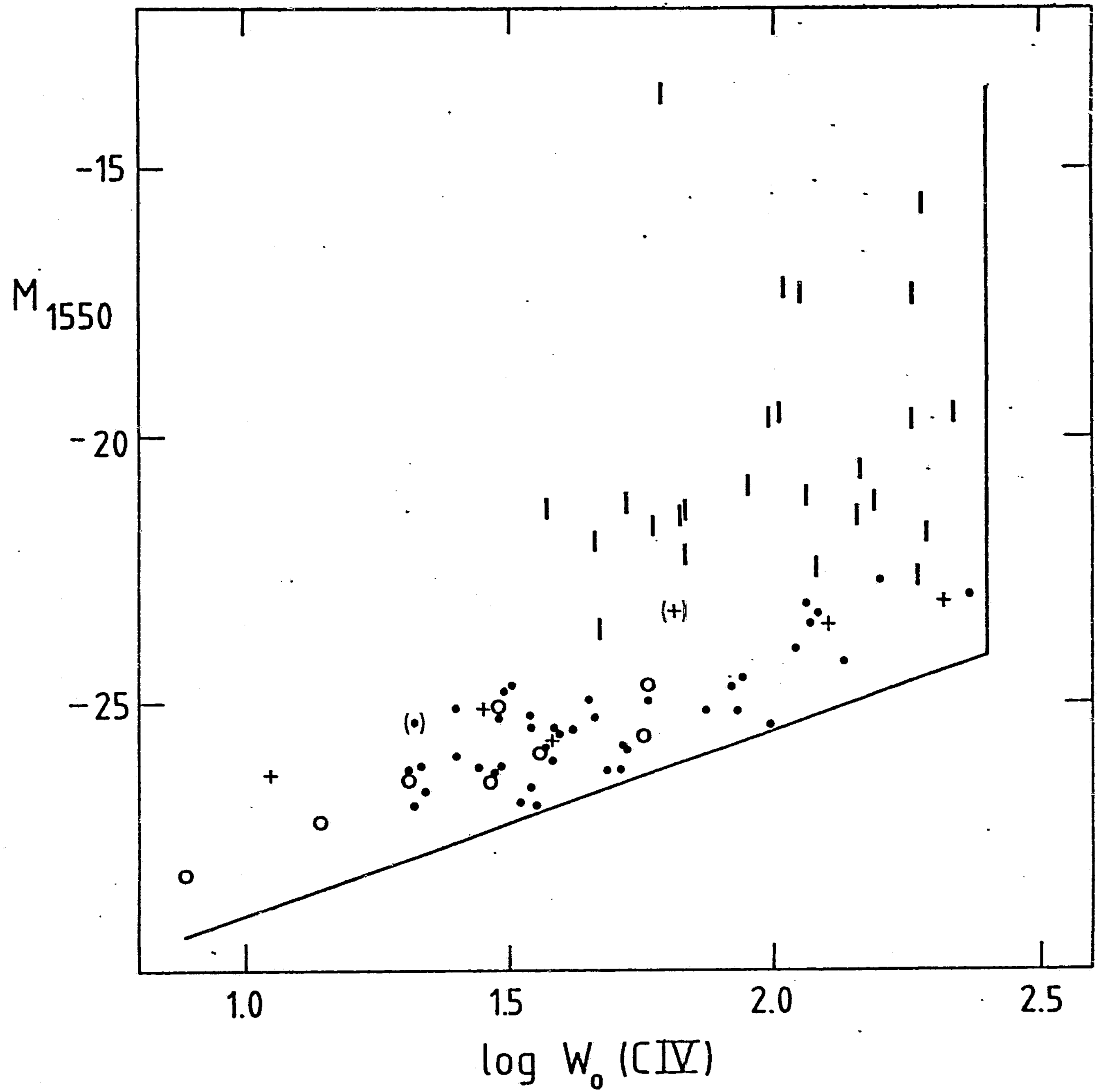
−25
−30
1.0
1.5
2.0
2.5
log W_0 (C IV)

5



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